COMMODITY TREATMENT

Hot-Water Immersion of Cape Jasmine Cuttings for Disinfestation of Green Scale (Homoptera: Coccidae)

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J. Econ. Entomol. 87(6): 1569–1573 (1994)

ABSTRACT Efficacy of hot-water immersion at 49°C from 0 to 10 min at 1-min intervals was determined for crawler, nymph, and adult stages of the green scale, *Coccus viridis* (Green), on propagative cuttings of cape jasmine, *Gardenia jasminoides* Ellis. Immersion in water at 49°C for 10 min was 99.9% effective against adults (n = 4,068) and crawlers (n = 8,278) and 99.7% effective against nymphs (n = 28,646). In another test, treatment of cape jasmine cuttings with hot water at 49°C for 10 min significantly increased shoot development. When cuttings were treated in hot water plus 0.8% indole-3-butyric acid (IBA) rooting powder or with IBA alone, cuttings had significantly more roots and greater root weight than cuttings treated in hot water alone or than control cuttings. We conclude that hot-water immersion will disinfest cape jasmine cuttings of green scale, increase shoot development, and will not negatively affect root development of cape jasmine. Hot-water immersion can be used in a systems approach to quarantine security for green scale on cape jasmine.

KEY WORDS *Coccus viridis*, quarantine, thermal death

HAWAIIAN AGRICULTURAL COMMODITIES are federally quarantined to prevent the spread of dangerous insect pests, including tephritid fruit flies and the green scale, *Coccus viridis* (Green), which are not widely prevalent or distributed throughout the continental United States (Animal and Plant Health Inspection Service 1989). The green scale, which is parthenogenetic and oviparous (Dekle 1976), occurs throughout the tropics, where it is a pest of fruit crops (including cacao, citrus, coffee, and guava) and ornamental crops (including *Gardenia* and *Ixora*) (Zimmerman 1948, Dekle 1976).

The pyrethroid fluvalinate is very effective against *C. viridis*, as demonstrated by recent field studies (Hata & Hara 1992, Reimer & Beardsley 1992). Reimer & Beardsley (1992) reported that one application of fluvalinate effectively controlled green scale densities on coffee to near zero for 106 d. Fluvalinate should be effective also against *C. viridis* when used as an insecticidal dip after harvest on propagative materials (Osborne 1986). However, the use of insecticidal dips after harvest poses hazards to humans and the environment; a nonchemical alternative, such as hot-water immersion, would be an ideal alternative.

Efficacy of hot-water immersion after harvest has been documented for treatment of gladiolus thrips, *Thrips simplex* (Morison), on gladiolus corms (Doucette 1933), of armored scales on bird of paradise leaves (Hara et al. 1993), of fruit flies and fungal diseases (Couey 1989, Klein & Lurie 1992), and of plant-parasitic nematodes (Agrios 1978).

Cape jasmine, *Gardenia jasminoides* Ellis, a preferred cultivated host of the green scale (Dekle 1976), is highly regarded for its elegant, fragrant flower for use in bouquets, corsages, and leis; as a landscape shrub or hedge; and as a popular conservatory plant in the continental United States (Neal 1965, Rauch 1979). A nonchemical treatment that can disinfest cape jasmine cuttings of *C. viridis* without affecting rooting would benefit the nursery industry. Here, we report the efficacy of hot-water immersion against *C. viridis* and the effect of hot water on rooting of cape jasmine cuttings.

Materials and Methods

Efficacy of Hot Water Against *C. viridis*. Infested cape jasmine cuttings (15.2 cm) with five to six leaves per cutting were obtained from unsprayed plantings in Hilo, HI. Only scales with

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no apparent signs of fungal infection were selected for our tests. Scale-infested leaves were immersed in water at 49°C for 0–10 min at 1-min intervals. Three replicates of each treatment (time) were done. Each treatment consisted of 100 adult scales and associated eggs, crawlers, and nymphs on infested leaves. Data were taken on the number of adults, nymphs, crawlers, and eggs from the most severely infested cuttings in a worst-case scenario. The heat-treatment tank was a stainless steel tank (106-liter) containing 76 liters of tap water as described by Hara et al. (1993). Constant temperature was maintained and monitored with two isotemp immersion circulators (model 730; Fisher, Pittsburgh, PA). A grid constructed of polyvinyl chloride pipe (1.3 cm i.d.) was used to hold the cuttings below the water surface. The water temperature was raised 0.1°C before immersion to compensate for the temperature decrease caused by immersing plant material at ambient temperature. Water temperature was maintained within ±0.1°C of 49°C throughout the treatment.

Immediately after treatment, the cuttings were cooled in a water bath at ambient temperatures (25.7–27.3°C) for 5 min. Controls were immersed in a water bath at ambient temperatures (25.7–27.3°C) for 15 min. The mortality of crawlers, nymphs, and adults was assessed 1 wk after treatment to allow live scales to recover from possible heat stupor, which is an immobile state caused by heat (Chapman 1969), and to allow easy identification of dead scales. Live adult scales were green, whereas dead scales were brown. The dead scales lacked leg and Malpighian tubule movement. Malpighian tubules appear as conspicuous, black, irregular, U-shaped tubules visible on the dorsum of the scale. The criterion for crawler mortality was lack of leg movement; the criterion for egg mortality was lack of emergence. Numbers of live and dead adults, nymphs, and crawlers were recorded and percentage of mortality calculated. Tests also were done to confirm treatment efficacy at 49°C for a 10-min immersion. Large numbers of scale-infested cuttings were treated by using immersion and evaluation procedures as described.

Effect of Hot Water on Rooting. Cape jasmine tip cuttings (15.2 cm) were obtained from an unsprayed planting at the University of Hawaii, Waiakea Agricultural Experiment Station in Hilo (elevation 183 m). Except for a pair of terminal leaves, all leaves were removed to facilitate planting. Cuttings were held in tap water for a maximum of 1 h until treatment. Treatments included hot water, hot water followed by 0.8% indole-3-butyric acid (IBA) rooting powder (Hormex, Brooker, North Hollywood, CA), 0.8% IBA alone, and untreated control. Each treatment was replicated three times with 10 cuttings per treatment. Cuttings were immersed in hot water at 49°C for 10 min. Immediately after treatment, 0.6 cm of the base of each cutting was trimmed. IBA was applied to the basal end of the appropriate treatments, and cuttings were planted in vermiculite at a depth of ≈3.8 cm in 10.2-cm-diameter plastic pots.

Pots were arranged in a complete, randomized experimental design on a bench in a fiberglass greenhouse. Cuttings were watered daily for 15 min with overhead sprinklers delivering 1.9 liters/min. Fifty-nine days after treatment, both the percentage of cuttings with roots and shoots and number of roots and shoots were recorded. Dry weights of roots were determined after drying at 46°C for 12 h. Cuttings were held in a greenhouse within which the average daily maximum and minimum temperatures were 36.4 ± 3.4 and 21.9 ± 0.9°C, respectively; the average daily maximum and minimum relative humidities were 95.7 ± 2.1 and 52.9 ± 11.2%, respectively.

Data Analysis. Because numbers of eggs, crawlers, and nymphs per adult were variable, the data were pooled to ensure adequate numbers of immature stages per exposure time. Percentage of mortality was transformed to arcsine square root and analyzed by linear regression. Data on rooting were subjected to analysis of variance (ANOVA), and means were separated by Waller-Duncan *k*-ratio *t*-test (SAS Institute 1987).

Results

Efficacy of Hot Water Against *C. viridis*. At 49°C, total mortality of adults, nymphs, and crawlers occurred after 10, 7, and 5 min, respectively (Table 1). Extrapolation of the dose–mortality regression equation estimated 100% mortality at 8.2 (SEM, 7.1–9.6), 7.8 (SEM, 6.5–9.8) and 7.7 (SEM, 6.0–10.8) min for adults, nymphs, and crawlers, respectively (Table 2). Confirmation of mortality at 49°C for 10 min was 99.9% effective against adults (n = 4,068) and crawlers (n = 8,278) and was 99.7% effective against nymphs (n = 28,646).

Effect of Hot Water on Rooting. Hot water did not negatively affect root development of cape jasmine cuttings. Cuttings treated with hot water plus IBA or with IBA alone had significantly (F = 7.76; df = 3, 8; P = 0.0094) more roots and greater dry weight (F = 8.77; df = 3, 8; P = 0.0066) than both hot water alone and the control (Table 3). We detected no significant differences in root weight or the number of roots per cutting between the control and the hot-water immersion treatment only and between hot water plus IBA and IBA only. Although not significantly different, hot-water-treated cuttings showed a trend of increasing percentage of shooting and rooting (Table 3). Young leaves of cape jasmine were injured by the hot-water treatment, which caused slight necrosis, but the mean number of

Table 1. Mean ± SEM percentage of mortality of adults, nymphs, and crawlers of *C. viridis* after hot-water immersion at 49°C

Exposure time, min	Adults (n = 300)	Nymphs	Crawlers
0	15.3 ± 4.3	21.0 ± 7.4 (2,809)	25.5 ± 7.6 (807)
1	21.7 ± 6.4	25.8 ± 11.5 (2,460)	53.8 ± 5.6 (530)
2	38.3 ± 9.5	78.8 ± 2.8 (2,617)	72.0 ± 11.1 (667)
3	61.3 ± 14.3	98.6 ± 0.7 (3,726)	96.4 ± 1.3 (631)
4	91.3 ± 1.9	99.3 ± 0.1 (3,320)	98.4 ± 0.8 (869)
5	96.3 ± 2.0	99.7 ± 0.3 (3,508)	100.0 ± 0.0 (913)
6	96.7 ± 3.3	99.8 ± 0.1 (3,066)	100.0 ± 0.0 (657)
7	100.0 ± 0.0	100.0 ± 0.0 (4,276)	100.0 ± 0.0 (826)
8	100.0 ± 0.0	100.0 ± 0.0 (3,797)	100.0 ± 0.0 (966)
9	99.7 ± 0.3	100.0 ± 0.0 (4,161)	100.0 ± 0.0 (1,249)
10	100.0 ± 0.0	100.0 ± 0.0 (3,701)	100.0 ± 0.0 (836)

Total numbers of scales treated are given in parentheses.

shoots was significantly (F = 4.48; df = 3, 8; P = 0.0399) increased by the hot-water treatment and by the hot water plus IBA treatment (Table 3).

Discussion

Hot-water immersion (49°C for 10 min) will disinfest cape jasmine cuttings infested with green scale, increase shoot development, and not negatively affect root development. Hot water, especially when combined with IBA, may have a positive effect on root development of cape jasmine cuttings, as indicated by the tendency of increase percentage of cuttings with roots and the additive increase in numbers of roots for the hot-water-plus-IBA-treated cuttings. Combining hot-water treatment with growth regulators or stimulants may result in significant increases in root development, shoot development, or both. The time-by-temperature regime of 49°C for 10 min is also in the range for fungi and nematode control (Agrios 1978, Klein & Lurie 1992). Thus, as a single nonchemical treatment after harvest, hot-water immersion not only will provide insect and disease disinfestation for propagative plant materials but also may stimulate both root and shoot development.

Although hot-water immersion is highly effective against green scales on cape jasmine cuttings, hot-water immersion at 49°C for 10 min alone does not meet the stringent probit 9 (99.9968% mortality) requirement necessary for an approved quarantine treatment (Baker 1939, Landolt et al. 1984, Jang 1991). Although hot-water immersion treatment at 49°C for 10 min exceeded the exposure time for 100% mortality extrapolated from the dose–mortality regression equation, we found survivors in our confirmatory test. These survivors were probably the result of the large number of scales per infested cutting. Our tests were done with severely infested cape jasmine cuttings; no field control resulted in as much as 92 adults, 1,316 nymphs, 177 crawlers, and 59 eggs per 15.2 cm cutting. However, commercially grown cuttings destined for export would not be nearly as infested. Chew & Ouye (1985) and Jang (1991) suggested that quarantine treatments based on load or degree of infestations would relate more realistically to a given treatment for quarantine security than strict adherence to a probit 9 security. We conclude that the level of field infestation should be known to develop a systems approach to quarantine security that can be adjusted to any specific risk level, including zero tolerance.

When quarantine regulations demand zero tolerance for green scale on cape jasmine, a systems approach to quarantine security (Jang & Moffitt 1994) similar to red ginger (Hata et al. 1992) could be implemented by use of field pest management and hot-water immersion. Field management of green scale would include use of

Table 2. Relationship between 49°C hot water exposure time (x) and percentage of mortality (y) for *C. viridis* crawlers, nymphs, and adults

Stage	Regression equation	n^a	r^2	MSE[b]	$P > F$
Adult	$y = 0.51 + 0.10\ (\pm 0.02)^c x^d$	11	0.87	0.03	0.0001
Nymph	$y = 0.79 + 0.10\ (\pm 0.02)x$	11	0.66	0.07	0.0022
Crawler	$y = 1.03 + 0.07\ (\pm 0.02)x$	11	0.56	0.04	0.0047

[a] Number of data points in regression; each data point represents arcsine (square root [percentage of mortality]) at a specific exposure time.
[b] Mean square error.
[c] Standard error of slope.
[d] Exposure time, minutes.

Table 3. Effects of hot water, IBA, and hot water plus IBA on mean ± SEM percentage of cuttings with shoots and roots, number of shoots and roots, and dry weight of roots

Treatment	% Shoots	% Roots	No. shoots	No. roots	Root dry weight, g
Hot water ± 0.8% IBA	90.0 ± 5.8NS	76.7 ± 13.3NS	5.3 ± 0.3a*	70.3 ± 11.5a**	0.09 ± 0.01a**
Hot water	93.3 ± 6.7	73.3 ± 3.3	5.3 ± 1.7a	9.4 ± 2.1b	0.03 ± 0.01b
0.8% IBA	70.0 ± 10.0	66.7 ± 8.8	1.9 ± 0.5b	58.6 ± 20.4a	0.06 ± 0.01a
Control	83.3 ± 8.8	60.0 ± 11.5	2.1 ± 0.3b	6.5 ± 3.1b	0.02 ± 0.01b

Data subjected to ANOVA. NS, Not significant. *, $P \leq 0.05$. **, $P \leq 0.01$. Means followed by the same letter in a column are not significantly different by Waller–Duncan *k*-ratio *t*-test, $k = 100$ [SAS Institute 1987].

the effective insecticide fluvalinate, the entomopathogenic fungus *Verticillium lecanii* (Zimmerman) (Reimer & Beardsley 1992), elimination of ants associated with green scale by chemical or physical exclusion methods (Reimer et al. 1993), or all three factors. These management procedures will reduce numbers of green scales to a level at which the hot-water immersion at 49°C for ≤10 min is totally effective. A final inspection of cuttings for live scales would ensure pest-free cape jasmine cuttings.

Further research is needed to determine the effectiveness of hot water on other pests of floriculture crops such as ants, aphids, mealybugs, mites, thrips, and whiteflies, as well as to determine heat sensitivity of flowers, foliage, and other propagative plant materials. Heat damage to flowers and foliage may be a limiting factor in some crops, but induction of heat tolerance in plants by a conditioning period is possible (Chan & Linse 1989, Couey 1989, Klein & Lurie 1992).

Acknowledgments

We thank Roderick Babayan (College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa) for technical assistance. Suggestions to improve the manuscript were provided by Stephen H. Saul (Department of Entomology, University of Hawaii at Manoa). This is Hawaii Institute of Tropical Agriculture and Human Resources Journal Series no. 3929.

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Received for publication 27 August 1993; accepted 24 May 1994.